Coherence of Sound and Understanding
Where it is Influenced in the Ocean

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LONG-TERM GOALS

The goal is to understand and reliably predict the temporal and spatial coherence of sound in the ocean due to influences from the sub-bottom, bottom, surface, and the sound speed and current fields in the fluid.

OBJECTIVES

The objective of this research is to develop software that accurately quantifies the spatial regions that influence the propagation of sound between a source and receiver in the ocean. Recent studies indicate that in some circumstances accurate predictions of temporal coherence can be made without knowing where the sound is being influenced (Spiesberger, 2011a,b). The present study will develop software to map where the sound is being influenced. Understanding where the sound is influenced will make it easier for scientists to develop theories to predict coherence. At very high acoustic frequencies, the regions that influence sound are shown by rays. Our research will develop software that shows the analogy of the ray path at all finite frequencies. Even moderately high frequencies are influenced by regions that are quite different than ray paths (Spiesberger, 2006b).

APPROACH

The maps where sounds are influenced between a source and receiver can be constructed by starting with the theory by Kirchoff and Raleigh from the 19th century (Born and Wolf, 1999). The approach uses openings in opaque screens to compute the received signal when the screen is placed anywhere between the source and receiver. Bowlin (1991) used this idea and showed that the regions of the ocean that influence sound for broadband signals are not given by the first Fresnel zone as some theories had assumed (Flatte *et al*, 1979). Spiesberger (2005,2006a) discussed subsequent problems associated with Flatte et al.'s theory to predict temporal coherence and developed an exact method for computing the regions of influence. In order to implement the approach, an approximate solution of the wave equation must be utilized that obeys reciprocity (Born and Wolf, 1999). Godin (1999) invented a parabolic approximation called OWWE that obeys reciprocity for media whose sound speed field varies in two spatial dimensions, normally with range and depth. Mikhin (2001) produced a numerical scheme to implement OWWE. In this contract, the regions of influence will be constructed through a

Report Documentation Page

1. REPORT DATE **30 SEP 2014**	2. REPORT TYPE	3. DATES COVERED **00-00-2014 to 00-00-2014**	
4. TITLE AND SUBTITLE **Coherence of Sound and Understanding Where it is Influenced in the Ocean**		5a. CONTRACT NUMBER	
		5b. GRANT NUMBER	
		5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)		5d. PROJECT NUMBER	
		5e. TASK NUMBER	
		5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Scientific Innovations, Inc,6 Derringdale Rd,Radnor,PA,19087**		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)	
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**			
13. SUPPLEMENTARY NOTES			
14. ABSTRACT			
15. SUBJECT TERMS			

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**3**	

collaboration between Dr. Mikhin at Acacia Research and Dr. Spiesberger at Scientific Innovations, Inc.

WORK COMPLETED

We demonstrated last year that Dr. Mikhin's numerical implementation of OWWE obeys reciprocity to very high accuracy for broadband signals, even when the bottom is not flat and the speed of sound varies vertically and horizontally. In 2014, software was written to compute the regions of influence from the outputs of OWWE.

RESULTS

We demonstrated that the correct region of influence was obtained for a simple test case where the speed of sound was a constant.

IMPACT/APPLICATIONS

Ray theory has wide applications. The current approach for computing the regions that influence sound are exact at all finite frequencies. Although the current approach is much more computationally demanding than tracing rays, computers get faster and we believe that the exact approach will someday be widely used for the same reasons that ray theory is widely used.

RELATED PROJECTS

There is another approach for mapping where a medium affects the propagation of sound between a source and receiver. The method was invented by Marquering et al. (1999) who applied it to seismic problems. Sarsoulis and Cornuelle (2004) used Marquering's approach for application to underwater acoustics. If one wishes to map the regions in space that affect sound, the method we are using is valid at all orders, and Marquering's approach is valid to first order in the perturbations with respect to the reference state. The approaches are not identical in other respects and both offer valuable insights into where sound is influenced.

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